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(54) **Method of making a core/pattern combination for producing a gas-turbine blade or component**

Verfahren zur Herstellung einer Kern/Muster-Kombination für die Produktion von Schaufeln oder
Teilen von Gasturbinen

Procédé pour la fabrication d'une combinaison avec de configuration de moyen pour la production de
lame ou component de turbine à gaz

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Description

This invention relates to a method of making a fused core/pattern combination for a cast gas-turbine blade or component as specified in the preamble of claim 1, for example as disclosed in US-A-4,863,538. In particular, the invention concerns a method of making a core/pattern combination for a cast gas-turbine blade or components by sequentially fusing regions of ceramic powder to form a layer of the core and adjacent thereto depositing wax or plastics material to form a region of the pattern in a layer-by-layer fashion to make a core/pattern combination.

A variety of methods are known for making ceramic cores suitable for use in producing cast gas-turbine blades. These prior-art methods include the step of covering the ceramic core with a protective coating such as an epoxy or phenolic resin to prevent the very fragile core from breaking during handling. However, the protective coating is undesirable in that it prevents subsequent mechanical work from being performed on the core, such as providing further detail or drilling holes in the core. Thereafter, the core is covered by a wax or plastics material by injection-moulding to form a pattern of the blade or component to be cast. These steps are expensive and time-consuming.

Thus, it would be desirable to provide a method of making a gas-turbine blade or component by a simple method which avoids the need to build ceramic core dies or wax-pattern dies, and eliminates the need for handling the core in a fragile state and eliminates the injection-moulding step to produce a pattern around the core.

A method of making a core/pattern combination according to the present invention is characterised by the features specified in the characterising portion of claim 1.

The present invention includes a method of making a core/pattern combination wherein the core has a configuration corresponding to a hollow portion of a gas-turbine blade or component and the pattern has a configuration corresponding to the blade or component. The inventive steps include sequentially fusing together a plurality of ceramic powder regions to form a portion of the core, and adjacent thereto fusing wax or plastics powder in regions to form a portion of the pattern, in a layer-by-layer fashion to produce a core/pattern combination. The present invention also includes a method of producing a fused core or pattern including sections having a thickness less than 0.508 mm (0.02 inches). The invention also includes a method of making a hollow gas-turbine blade using molten alloy at temperatures ranging from about 649°C (1200°F) to about 1815.5°C (3300°F).

As stated above, the invention includes a method of making a core/pattern combination by sequentially fusing together regions of ceramic material (or powder) and regions of wax or plastic powder in a layer-by-layer fashion to produce the core/pattern combination. Pref-

erably, the layers of powder are fused together by directing a laser beam onto successive layers of powder including quartz. A suitable apparatus and method of operation for accomplishing the laser fusion of powdered material is described in U.S. patent No.4,863,538, the disclosure of which is hereby incorporated by reference. The fusing together of the powder layers may be accomplished by directing wave energy onto predetermined patterns of the powder. Such wave energy may include an electron beam.

As described in U.S. patent No.4,863,538, an apparatus useful in connection with the present invention includes a laser or other directed energy source which is selectable for emitting a beam on a target area where a part is to be produced. A powdered dispensing system deposits powder onto the target area. A control mechanism operates to selectively fuse or sinter only the powder disposed within the fine boundaries to produce the desired layer of the part. The control mechanism operates the laser to selectively sinter or fuse sequential layers of the powder, producing a completed part comprising a plurality of layers sintered or fused together. The defined boundaries of each layer correspond to respective cross-section regions of the part. The control mechanism may include a computer such as a CAD/CAM system to determine the defined boundaries of each layer. Given the overall dimensions and configuration of the part to be produced, the computer determines the defined boundaries for each layer and operates a laser-control mechanism in accordance with the defined boundaries.

The laser-control mechanism may include a means for directing the laser beam on the target area and a means for modulating the laser beam between on and off positions or a shuttering means to selectively sinter or fuse the powder in the target area to produce varying configurations as desired. The directing mechanism may operate to move the aim of the laser beam in a continuous raster scan of the target area. A modulating mechanism turns the laser beam on and off so that the powder is sintered or fused only when the aim of the laser beam is within the defined boundaries for the particular layer. The directing mechanism may aim the laser beam only within defined boundaries for the particular layer so that the laser beam can be left on continuously to sinter the powder within the defined boundaries of the particular layer.

The directing mechanism may move the laser beam in a respective raster scan of the target area using mirrors driven by galvanometers. A first mirror may reflect the laser beam to a second mirror which may reflect the beam onto the target. Movement of the first mirror by its galvanometer shifts the laser beam generally in one direction in the target area. Movement of the second mirror by its galvanometer shifts the laser beam in the target area in a second direction. The mirrors may be oriented relative to each other so that the first and second directions are generally perpendicular to each other. This arrangement allows for many different types

of scanning patterns of the laser beam in the target area, including a raster scan pattern.

The dispensing of the powder may be assisted by using a confinement structure which defines the outer perimeter of each layer. Each layer may be defined by a separate confinement structure or the entire part may be defined by a single confinement structure. When passages or voids in a particular layer are desirable, these may be obtained by simply not sintering or fusing the powder in the area for the void or passage. After the selective portions of the layer have been fused, the loose powder may be brushed away or blown-off to define the void or passage. Alternatively, a passage or void may be defined by placing a different type of material on top of the previous fused layer at the location of the void or passage and depositing the next loose powder layer around the insert and thereafter fusing the powder. Preferably, the insert would be constructed of material and positioned such that it may be dissolved or otherwise removed after the powder is fused together to form the void or passage.

The steps of the method of the present invention include the following. Firstly, a three-dimensional configuration of the hollow portion of a gas-turbine blade or component must be determined. Secondly, a three-dimensional configuration of the blade or component must be determined. The core may be produced by fusing together layers of ceramic powder, preferably quartz, in a layer-by-layer fashion corresponding to discrete cross-sectional regions of the hollow portion of the gas-turbine blade. A first layer of powder comprising ceramic material is deposited on a substrate in a predetermined pattern corresponding to a first cross-sectional region of the hollow portion of the gas-turbine blade. The first layer of powder is fused together by directing a laser beam over the predetermined pattern of the first layer of ceramic powder to form a first fused layer of ceramic having the shape of the first cross-sectional region of the hollow portion. Likewise, the pattern may be produced by fusing together regions of wax or plastics material, which may be deposited adjacent the ceramic powder or fused ceramic, and in a manner consistent with forming each layer of the core. A second layer of ceramic powder is deposited on the first layer of fused ceramic or fused wax or plastics material in a second predetermined pattern corresponding to a second cross-sectional region of the hollow portion which is immediately adjacent to the first cross-sectional region. The second layer of powder is fused together by directing a laser beam over the second predetermined pattern to form a second fused layer of ceramic having the shape of the second cross-sectional region of the hollow portion, and so that the second fused layer is fused to the first fused layer. The second layer of the pattern is formed in a similar fashion as described above. Successive layers of powder are deposited onto previous fused layers in predetermined patterns corresponding to respective cross-sectional regions of the hollow portion of the core and of the pattern. Each of the successive

layers of powder is fused together to form successive fused layers, wherein each of the successive fused layers are fused to a previously fused layer to form the core having a configuration corresponding to the hollow portion of the gas-turbine blade or component, and a pattern having a configuration corresponding to the blade or component.

The core/pattern combination may be used to make a gas-turbine blade. A readily removable casting mould is placed around the pattern and the core so that it conforms to the outer surface of the pattern. The wax or plastics pattern may be removed in a manner known in the art, such as pre-heating the wax pattern or dissolving the plastics pattern. Molten alloy is poured into the casting mould so that the molten alloy fills the mould, and the molten alloy is thereafter solidified. The cast moulding may be broken away and the core removed with molten caustic soda.

Preferably, the ceramic powder comprises quartz. The quartz may comprise alpha or beta quartz. All powders will have an average particle size under 100 micrometres. When the quartz powder is alpha/beta quartz, a core made therefrom can withstand the casting of a molten alloy having a temperature ranging from about 649°C (1200°F) to about 1815.5°C (3300°F).

The wax or plastics powder used to produce the pattern may have a similar size and configuration. Each layer of fused pattern may have a thickness of about 0.254 to 1.524 mm (0.010 to 0.06 inches).

Claims

1. A method of making a core/pattern combination by sequentially depositing layers of a fusible powder upon a substrate and sequentially fusing said layers together by means of a laser beam, characterised in that said method comprises the steps of: depositing a first layer of powder comprising a ceramic material onto said substrate in a predetermined pattern corresponding to a first cross-sectional region of a hollow portion of a gas-turbine blade or component; fusing together said first layer of ceramic powder by directing said laser beam over the predetermined pattern of said first layer of powder to form said fused layer of ceramic having a shape of said first cross-sectional region of said hollow portion; depositing a first layer of powder comprising at least one selected from the group consisting of wax and plastics material on said substrate in a predetermined pattern corresponding to a first cross-sectional region of said blade or component; fusing together said first layer of wax or plastics powder by directing a laser beam over the predetermined pattern corresponding to said first cross-section of blade or component to form a fused layer of wax or plastics material having a shape corresponding to said first cross-sectional region of said blade or component; the fused regions of ceramic material and the fused regions

of wax or plastics material of the first layer forming a first fused layer; depositing a second layer of ceramic powder onto said first fused layer in a second predetermined pattern corresponding to a second cross-sectional region of said hollow portion which is immediately adjacent said first cross-sectional region of said hollow portion same; fusing said second layer of ceramic powder by directing a laser beam over said second predetermined pattern of said hollow portion to form a second fused layer of ceramic material having the shape of said second cross-sectional region of said hollow portion, and so that said second fused layer of ceramic material is fused to said first fused layer; depositing a second layer of wax or plastic powder onto said first fused layer in a second predetermined pattern corresponding to a second cross-sectional region of said blade or component which is immediately adjacent to the first cross-sectional region of said blade or component; fusing said second layer of wax or plastics material by directing a laser beam over said second predetermined pattern of said blade or component to form a second fused layer of wax or plastics material having the shape of said second cross-sectional region of said blade or component, and so that said fused layer of wax or plastics material is fused to said first fused layer; and depositing successive layers of powder onto previous fused layers of ceramic material or fused layers of wax or plastics material in predetermined patterns corresponding to a respective cross-sectional regions of said hollow portion and said blade or component, and fusing each of said successive layers of powder to form successive fused layers, wherein each of said successive fused layers is fused to a previous fused layer to form said core having a configuration corresponding to said hollow portion of said gas-turbine blade and a pattern having a configuration corresponding to said blade or component.

2. A method according to claim 1 in which said ceramic powder comprises quartz.
3. A method according to claim 1, in which said core has sections having a thickness less than 1.524 mm (0.06 of an inch).
4. A method of making a gas-turbine blade or component according to any one of claims 1 to 3, in which the method includes placing a readily-removeable casting mould around said pattern and core, which casting mould conforms to said pattern; removing said pattern to leave a void; pouring a molten alloy into said casting mould to fill said void; solidifying said alloy; removing said casting mould; and removing said core with liquid caustic soda.
5. A method according to claim 4, in which said molten

alloy has a temperature ranging from about 649°C (1200°F) to about 1815.5°C (3300°F).

Patentansprüche

1. Verfahren zur Herstellung einer Kern/Muster-Kombination durch aufeinanderfolgendes Auftragen von Schichten eines schmelzbaren Pulvers auf ein Substrat und aufeinanderfolgendes Zusammenschmelzen der Schichten mittels eines Laserstrahls, dadurch gekennzeichnet, daß das verfahren die folgenden Schritte umfaßt: Auftragen einer ersten Schicht aus Pulver, das Keramikmaterial umfaßt, auf das Substrat in einem vorgegebenen Muster, das einem ersten Querschnittsbereich eines hohlen Abschnitts einer Gasturbinenschaufel bzw. eines Gasturbinenbestandteils entspricht; Zusammenschmelzen der ersten Schicht aus Keramikpulver durch Führen des Laserstrahls über das vorgegebene Muster der ersten Schicht aus Pulver, um die geschmolzene Schicht aus Keramik zu bilden, die eine Form des ersten Querschnittsbereichs des hohlen Abschnitts aufweist; Auftragen einer ersten Schicht aus Pulver, das mindestens ein Material umfaßt, das aus der Gruppe, die Wachs und Kunststoff umfaßt, ausgewählt wurde, auf das Substrat in einem vorgegebenen Muster, das einem ersten Querschnittsbereich der Schaufel bzw. des Bestandteils entspricht; Zusammenschmelzen der ersten Schicht aus Wachs bzw. Kunststoffpulver durch Führen eines Laserstrahls über das vorgegebene Muster, das dem ersten Querschnitt der Schaufel bzw. des Bestandteils entspricht, um eine geschmolzene Schicht aus Wachs bzw. Kunststoff zu bilden, deren Form dem ersten Querschnittsbereich der Schaufel bzw. des Bestandteils entspricht; wobei die geschmolzenen Bereiche aus Keramikmaterial und die geschmolzenen Bereiche aus Wachs bzw. Kunststoff der ersten Schicht eine erste geschmolzene Schicht bilden; Auftragen einer zweiten Schicht aus Keramikpulver auf die erste geschmolzene Schicht in einem zweiten vorgegebenen Muster, das einem zweiten Querschnittsbereich des hohlen Abschnitts, der unmittelbar angrenzend an den ersten Querschnittsbereich desselben hohlen Abschnitts angeordnet ist, entspricht; Schmelzen der zweiten Schicht aus Keramikpulver durch Führen eines Laserstrahls über das zweite vorgegebene Muster des hohlen Abschnitts, um eine zweite geschmolzene Schicht aus Keramikmaterial zu bilden, die die Form des zweiten Querschnittsbereichs des hohlen Abschnitts aufweist, und so, daß die zweite geschmolzene Schicht aus Keramikmaterial auf die erste geschmolzene Schicht aufgeschmolzen wird; Auftragen einer zweiten Schicht aus Wachs bzw. Kunststoffpulver auf die erste geschmolzene Schicht in einem zweiten vorgegebenen Muster, das einem zweiten Querschnittsbereich der Schau-

- fel bzw. des Bestandteils, der unmittelbar angrenz-
 end an den ersten Querschnittsbereich der
 Schaufel bzw. des Bestandteils angeordnet ist, ent-
 spricht; Schmelzen der zweiten Schicht aus Wachs
 bzw. Kunststoff durch Führen eines Laserstrahls
 über das zweite vorgegebene Muster der Schaufel
 bzw. des Bestandteils, um eine zweite geschmol-
 zene Schicht aus Wachs bzw. Kunststoff zu bilden,
 die die Form des zweiten Querschnittsbereichs der
 Schaufel bzw. des Bestandteils aufweist, und so,
 daß die geschmolzene Schicht aus Wachs bzw.
 Kunststoff auf die erste geschmolzene Schicht auf-
 geschmolzen wird; und Auftragen aufeinanderfol-
 gender Schichten aus Pulver auf vorhergehende
 geschmolzene Schichten aus Keramikmaterial oder
 geschmolzene Schichten aus Wachs bzw. Kunst-
 stoff in vorgegebenen Mustern, die einem jeweili-
 gen Querschnittsbereich des hohlen Abschnitts und
 der Schaufel bzw. des Bestandteils entsprechen,
 und Schmelzen jeder der aufeinanderfolgenden
 Schichten aus Pulver, um aufeinanderfolgende
 geschmolzene Schichten zu bilden, bei denen jede
 der aufeinanderfolgenden geschmolzenen Schich-
 ten auf eine vorhergehende geschmolzene Schicht
 aufgeschmolzen ist, um den Kern zu bilden, der
 eine Konfiguration aufweist, die dem hohlen
 Abschnitt der Gasturbinenschaufel entspricht und
 um ein Muster zu bilden, das eine Konfiguration
 aufweist, die der Schaufel bzw. dem Bestandteil
 entspricht.
2. Verfahren nach Anspruch 1, bei dem das Keramik-
 pulver Quarz umfaßt.
 3. Verfahren nach Anspruch 1, bei dem der Kern Teil-
 bereiche aufweist, die eine Dicke von weniger als
 1,524 mm (0,06 Inch) haben.
 4. Verfahren zur Herstellung einer Gasturbinenschau-
 fel oder eines Gasturbinenbestandteils nach einem
 der Ansprüche 1 bis 3, bei dem das Verfahren Fol-
 gendes umfaßt: Anbringen einer leicht entfernbaren
 Gießform um das Muster und den Kern herum,
 wobei die Gießform dem Muster entspricht; Entfer-
 nen des Musters, um einen Hohlraum frei zu las-
 sen; Gießen einer geschmolzenen Legierung in die
 Gießform, um den Hohlraum zu füllen; Aushärten
 der Legierung; Entfernen der Gießform; und Entfer-
 nen des Kerns mit flüssiger Natronlauge.
 5. Verfahren nach Anspruch 4, bei dem die Schmelz-
 legierung eine Temperatur aufweist, die von unge-
 fähr 649°C (1200°F) bis ungefähr 1815,5°C
 (3300°F) reicht.
- Revendications**
1. Procédé de production d'une combinaison de
 noyau/modèle en déposant successivement des

couches d'une poudre fusible sur un substrat et en
 joignant ensemble lesdites couches par fusion suc-
 cessive de celles-ci au moyen d'un rayon laser,
caractérisé en ce que ledit procédé comprend les
 étapes suivantes : déposer une première couche
 de poudre comprenant une matière céramique sur
 ledit substrat en formant un modèle prédéterminé
 correspondant à une première région de coupe
 transversale d'une portion creuse d'une ailette ou
 d'un élément de turbine à gaz ; joindre par fusion
 ladite première couche de poudre céramique en
 dirigeant ledit rayon laser sur le modèle prédéter-
 miné de ladite première couche de poudre afin de
 former ladite couche fondue de céramique présen-
 tant une forme de ladite première région de coupe
 transversale de ladite portion creuse ; déposer une
 première couche de poudre comprenant au moins
 une poudre sélectionnée à partir du groupe consti-
 tué par la cire et la matière plastique sur ledit sub-
 strat en formant un modèle prédéterminé
 correspondant à une première région de coupe
 transversale de ladite ailette ou dudit élément ; join-
 dre par fusion ladite première couche de poudre de
 cire ou de matière plastique en dirigeant un rayon
 laser sur le modèle prédéterminé correspondant à
 ladite première coupe transversale de l'ailette ou de
 l'élément afin de former une couche fondue de cire
 ou de matière plastique présentant une forme cor-
 respondant à ladite première région de coupe
 transversale de ladite ailette ou dudit élément ; les
 régions fondues de matière céramique et les
 régions fondues de cire ou de matière plastique de
 la première couche formant une première couche
 fondue ; déposer une seconde couche de poudre
 céramique sur ladite première couche fondue en
 formant un second modèle prédéterminé corres-
 pondant à une seconde région de coupe transver-
 sale de ladite portion creuse qui est immédiatement
 adjacente à ladite première région de coupe trans-
 versale de ladite portion creuse de celle-ci ; provo-
 quer la fusion de ladite seconde couche de poudre
 céramique en dirigeant un rayon laser sur ledit
 second modèle prédéterminé de ladite portion
 creuse afin de former une seconde couche fondue
 de matière céramique présentant la forme de ladite
 région de coupe transversale de ladite portion
 creuse, et de sorte que ladite seconde couche fon-
 due de matière céramique est jointe par fusion à
 ladite première couche fondue ; déposer une
 seconde couche de poudre de cire ou de matière
 plastique sur ladite première couche fondue en for-
 mant un second modèle prédéterminé correspon-
 dant à une seconde région de coupe transversale
 de ladite ailette ou dudit élément qui est immédia-
 tement adjacent(e) à la première région de coupe
 transversale de ladite ailette ou dudit élément ; pro-
 voquer la fusion de ladite seconde couche de cire
 ou de matière plastique en dirigeant un rayon laser
 sur ledit second modèle prédéterminé de ladite

aillette ou dudit élément afin de former une seconde couche fondue de cire ou de matière plastique présentant la forme de ladite seconde région de coupe transversale de ladite ailette ou dudit élément, et de sorte que ladite couche fondue de cire ou de matière plastique est jointe par fusion à ladite première couche fondue ; et déposer des couches successives de poudre sur des couches fondues précédentes de matière céramique ou des couches fondues de cire ou de matière plastique en formant des modèles prédéterminés correspondant à des régions respectives de coupe transversale de ladite portion creuse et de ladite ailette ou dudit élément, et provoquer la fusion de chacune desdites couches successives de poudre afin de former des couches fondues successives, dans lequel chacune desdites couches fondues successives est jointe par fusion à une couche fondue précédente afin de former ledit noyau présentant une configuration correspondant à ladite portion creuse de ladite ailette de turbine à gaz et un modèle présentant une configuration correspondant à ladite ailette ou audit élément.

2. Procédé selon la revendication 1, dans lequel ladite poudre céramique comprend du quartz.
3. Procédé selon la revendication 1, dans lequel ledit noyau possède des sections dont l'épaisseur est inférieure à 1,524 mm (0,06 pouce).
4. Procédé de production d'une ailette ou d'un élément de turbine à gaz selon l'une quelconque des revendications 1 à 3, dans lequel le procédé comporte : placer un moule à fonder retirable en bloc autour dudit modèle et dudit noyau, lequel moule a fonder épouse ledit modèle ; retirer ledit modèle afin de laisser un vide ; verser un alliage fondu dans ledit moule à fonder afin de remplir ledit vide ; solidifier ledit alliage ; retirer ledit moule à fonder ; et retirer ledit noyau à l'aide de soude caustique liquide.
5. Procédé selon la revendication 4, dans lequel ledit alliage fondu a une température allant d'environ 649°C (1200°F) à environ 1815,5°C (3300°F).

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